A Bibliometric Voyage through Scientific Creativity in Chemistry

Abu Aswatudali Syawal Muhammad[1], Salmiza Saleh[2*]

[1,2]School of Educational Studies, USM, Penang

[*]Corresponding Author

DOI: https://dx.doi.org/10.47772/IJRISS.2025.90300096

Received: 16 February 2025; Revised: 27 February 2025; Accepted: 04 March 2025; Published: 01 April 2025

ABSTRACT

Scientific creativity is a vital element in driving innovation and progress in chemistry. This bibliometric study addresses key research questions to explore trends and patterns in scientific creativity within this field. The study investigates six key aspects: (1) the research trends categorized based on the year of publication, (2) the most productive authors contributing to the subject, (3) the types of documents used in this research domain, (4) network mapping based on popular keywords, (5) collaboration networks through co-authorship by countries, and (6) citation patterns by country. To answer these questions, bibliometric data were extracted from the Scopus database. The data were analyzed using VOSviewer to generate network maps and measure the impact of various research entities. The results revealed that yearly trends indicated a steady rise in research outputs from 2020 to 2023, with a peak in 2023 and a minor decline in 2024. Meanwhile, Ernawati, Haryanto, and Rahmawati are the most productive authors shaping the field. Journal articles dominate the research output (90%), reflecting their critical role in disseminating high-quality, peer-reviewed work. Keyword network mapping reveals a focus on multi-disciplinary, with themes such as STEM education, critical thinking, and the integration of creativity in chemistry classrooms. Co-authorship analysis indicates that Indonesia leads regional collaborations with Turkey and Malaysia, while developed nations like the US and Germany play vital roles in global partnerships. China's contributions further broaden the field's scope. Citation-based mapping identifies Indonesia, China, and Germany as top contributors, showcasing global chemistry research's interconnected and collaborative nature. These findings offer a thorough overview of the current state of scientific creativity in chemistry, emphasizing the significance of inclusive research initiatives, interdisciplinary strategies, and global partnerships. The insights are valuable for researchers, policy-makers, and educators in prioritizing future research directions, fostering collaborations, and addressing gaps to promote sustained growth in the field.

Keywords: Scientific creativity, chemistry, bibliometric, network mapping, research trends

INTRODUCTION

The scientific creativity skill among students has become a focal point of contemporary research in chemistry education. It reflects the crucial role of the skill in helping students advance the discipline. Scientific creativity in chemistry education is essential for equipping students with the skill to solve real-world problems, fostering traits including flexibility and originality in problem-solving (Nurdullayevna & Kuanishkyzy, 2024; Nursiwan & Hanri, 2023). Students who portray this trait are expected to have the ability to think of new ways to conduct experiments, create innovative materials, and solve scientific problems in novel ways. This explanation aligns with the current trend of teaching students to think creatively in chemistry classes, which is seen as an essential competency for promoting innovation and solving real-world problems. This concept of creativity also emphasizes the significance of divergent thinking traits, including fluency, flexibility, and originality, in solving theoretical and practical problems (Ramly et al., 2022).

Despite its importance, incorporating creativity into chemistry education often faces sophisticated challenges. Teacher-centered approaches and the emphasis on standardized testing often hinder the development of scientific creativity skills among students. Besides, a general lack of professional development opportunities among teachers limits their capacity to implement innovative teaching strategies during chemistry lessons. Although frameworks that promote creativity exist, their inconsistent application in classrooms highlights the need for targeted interventions and resources (Nursiwan et al., 2023). {Bibliography}

Nonetheless, new opportunities for encouraging creativity in chemistry education are emerging due to digital tools and technology developments, innovative pedagogical strategies, and interdisciplinary approaches. Technological advancements enhance understanding and address traditional barriers, making chemistry education more accessible, interactive, and impactful (Stepanov & Orzhekovskiy, 2022). Besides, approaches such as collaborative problem-solving, inquiry-based learning, and project-based activities also improve students' understanding and address longstanding barriers to creativity in chemistry education by promoting active participation and intellectual curiosity (Singh & Kaushik, 2020). Together, these opportunities highlight the potential to effectively solve the challenges in integrating creativity into chemistry education.

RESEARCH QUESTION

Considering the focus established in this study, the research aims to address the following six bibliometric research questions:

1. What are the research trends of scientific creativity in chemistry according to the year of publication?
2. Who are the most productive authors of research?
3. What type of documents are used for the subject of research?
4. What is network mapping based on the popular keywords related to the study?
5. What is network mapping based on co-authorship countries' collaboration?
6. What is network mapping based on citation by country?

LITERATURE REVIEW

In the modern era, scientific creativity has become a critical competency in chemistry education, with significant implications for addressing contemporary global challenges such as sustainability and technological innovation (Lai et al., 2024). There is a growing emphasis on fostering creativity within chemistry education to facilitate the development of innovative solutions through creative thinking and interdisciplinary approaches. Research by Xu et al. (2024) underscores the role of inquiry-based learning in boosting students' problem-solving abilities and scientific comprehension. As chemistry programs evolve to address the needs of the future workforce, they increasingly incorporate creative competencies like critical thinking and imaginative experimentation (Tseng et al., 2024). This evolving focus highlights the ongoings trends in scientific creativity in chemistry education, aligning with the research on how creativity is integrated into the curriculum to enhance problem-solving and innovation.

A body of research highlights the significance of creative pedagogical approaches in promoting scientific creativity. Notable studies by Kocoglu and Kanadli (2024) indicate that argumentation-based instruction significantly enhances students' academic achievements while fostering creative thinking skills. Similarly, research by Pertiwi et al. (2024) delves into the impact of STEM-based pedagogies and project-based learning in developing critical thinking and problem-solving abilities, particularly in experimental and applied chemistry contexts. Lai et al. (2024) further support these findings, emphasizing that collaborative problem-solving encourages students to generate creative ideas. These studies contribute to the body of work that identifies the most productive authors researching creative pedagogical approaches in the field of scientific creativity in chemistry.

Existing literature on creativity in chemistry education focuses on a variety of teaching strategies. The research primarily examines the effectiveness of specific instructional methods, such as argumentation and inquiry-based learning. However, gaps exist in understanding the long-term effects of these strategies. Xu et al. (2024) highlight the difficulty in comparing studies due to the lack of standardized measures for assessing creativity. Additionally, Pertiwi et al. (2024) point out the need for more inclusive studies that account for socio-cultural factors impacting the development of creativity. This reflects the variety of document types used in research, emphasizing the need for a diverse set of studies that incorporate different teaching methods and assessment tools.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue III March 2025

While research on creative teaching methods has progressed, important gaps remain in the field. Lai et al. (2024) emphasize the need for longitudinal studies to track the development of students' creative abilities throughout their academic careers. Furthermore, there is limited research into how digital tools and virtual labs might foster creativity in chemistry education, as noted by Kocoglu and Kanadli (2024). Addressing these gaps could provide a clearer understanding of how creativity evolves in educational settings and the role of digital technologies in enhancing creative thinking. The network mapping of keywords in this field could help identify these gaps and shed light on emerging trends in the integration of technology and creativity.

The literature reveals a lack of diversity in studies on creativity, particularly in terms of socio-cultural factors. Pertiwi et al. (2024) call for more research on the influence of socio-cultural contexts on creativity in chemistry education. This gap underscores the need for broader, more inclusive studies to explore the impact of different cultural perspectives on the development of scientific creativity. The network mapping based on co-authorship countries' collaboration is critical in identifying international trends and gaps in the global research landscape on scientific creativity in chemistry.

Despite advancements in creative teaching methodologies, there are still significant gaps in assessing creativity and understanding its socio-cultural influences. Lai et al. (2024) stress the need for reliable assessment methods to evaluate creative thinking in chemistry education. Moving forward, research should focus on developing these methods and exploring how various teaching approaches can be tailored to diverse classroom environments to support creativity in students. Citation-based network mapping by country could offer valuable insights into the global contributions to the field and how different regions approach creativity in chemistry education.

The literature underscores the importance of fostering scientific creativity in chemistry education to prepare students for future challenges. Although significant progress has been made in developing creative teaching methodologies, areas such as assessment techniques and understanding socio-cultural influences remain underexplored. To fully integrate creativity into chemistry education, focused research is needed to fill these gaps and provide more comprehensive insights into effective teaching practices. A bibliometric analysis could offer valuable insights into the evolving trends in this field, revealing the most productive authors and types of documents used in research on scientific creativity. Furthermore, exploring keywords, citation patterns and collaborative networks through such an analysis could highlight the global landscape of research on scientific creativity in chemistry education, offering a clearer direction for future studies.

METHODOLOGY

This study employed bibliometric analysis to systematically examine scientific creativity in chemistry education. Bibliometric analysis, a quantitative method for evaluating research trends and scholarly impact, involves collecting, organizing, and analyzing bibliographic data from scientific publications (Alves et al., 2021; Verbeek et al., 2002). A structured approach was adopted, beginning with the identification of relevant keywords and search parameters to ensure comprehensive data collection (Fahimnia et al., 2015). The SCOPUS database, known for its extensive coverage of peer-reviewed academic publications, was selected as the primary data source (Al-Khoury et al., 2022; Di Stefano et al., 2010). A systematic search was conducted to retrieve relevant journal articles published between 2020 and December 2024, while books, conference proceedings, and lecture notes were excluded to maintain data reliability (Gu et al., 2019).

The collected data underwent bibliometric analysis, including general descriptive statistics such as publication trends, journal distribution, and primary author classifications. To provide deeper insights, advanced techniques such as co-citation analysis and keyword mapping were applied to identify emerging themes and research collaborations (Wu & Wu, 2017). These methods facilitated a structured examination of the intellectual landscape, major scholarly contributions, and interdisciplinary aspects of scientific creativity in chemistry education. Additionally, Elsevier's Scopus database was leveraged to ensure comprehensive coverage of high-impact research, enabling a robust evaluation of the field's historical development and significant contributions.

Data Search Strategy

The study utilized a screening sequence to determine the search terms for article retrieval. The study was initiated by querying the Scopus database with online ALL ("scientific creativity") OR ("creative thinking") OR ("creativity in science") AND ("chemistry") OR ("chemical education") OR ("chemistry learning"), thereby assembling 3567 articles. Afterwards, the query string was revised based on the selection criterion. This adjustment resulted in the compilation of 1346 articles, which underwent further refinement to focus students as learners, specifically emphasizing the search terms "scientific creativity" AND "chemistry." The final refinement produced 200 results, which were utilized for bibliometric analysis. By December 2024, all articles from the Scopus database related to scientific creativity, with a focus on chemistry or related subject areas, were included in the study.

Table 1: The Search String

Scopus	ALL ((("scientific creativity") OR ("creative thinking") OR ("creativity in science")) AND (("chemistry") OR ("chemical education") OR ("chemistry learning"))) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "CHEM")) AND (EXCLUDE (DOCTYPE, "ed") OR EXCLUDE (DOCTYPE, "no") OR EXCLUDE (DOCTYPE, "tb")) AND (LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2024)).

Table 2: The Selection Criterion is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2020 – 2024	< 2020
Literature type	Book/chapter, Article, Conference	Conference review, Note, Erratum, Editorial, Letter

Data Analysis

Data sets in Plain Text format, containing details such as publication year, title, author name, journal, citations, and keywords, were retrieved from the Scopus database for the period spanning 2020 to December 2025. These data sets were analyzed using VOSviewer software, version 1.6.19, employing clustering and mapping techniques to produce visual representations. VOSviewer, created by Nees Jan Van Eck and Ludo Waltman at Leiden University in the Netherlands (Van Eck & Waltman, 2010, 2017), is a highly user-friendly bibliometric tool designed for the visualization and analysis of scientific literature. Unlike Multidimensional Scaling (MDS), VOSviewer places the items in a low-dimensional space where the proximity of items reflects their similarity and relatedness (Van Eck & Waltman, 2010). Meanwhile, VOSviewer shares similarities with MDS Appio et al. (2014). It is a more appropriate method for normalizing co-occurrence frequencies, such as the association strength (*ASij*), which is computed as (Van Eck & Waltman, 2007):

ASij ¼ Cij,

Wiwj.

In bibliometric analysis, i and j denote two distinct analyzed entities, such as articles, authors, journals, or keywords, contingent on the context of the analysis. The index employed is "proportional to the ratio between the observed number of co-occurrences of i and j and the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent" (Van Eck & Waltman, 2010). Therefore, using this index, VOSviewer arranges items on a map by minimizing the weighted sum of the squared distances between each pair of items. The normalization used was LinLog/modularity, according to Appio et al. (2014). Additionally, by utilizing visualization techniques via VOSviewer on the dataset, patterns based on mathematical relationships were revealed, and analyses such as keyword co-occurrence, citation analysis, and co-citation analysis were performed.

The development of a research area over time can be examined through keyword co-occurrence analysis (Zhao,

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue III March 2025

2017), which has been effective in identifying popular topics across different fields (Li et al., 2016). On the other hand, citation analysis is valuable for identifying key research issues, trends, and techniques and examining the historical significance of a discipline's primary focus (Allahverdiyev & Yucesoy, 2017). Document co-citation analysis is one of the commonly used bibliometric techniques (Appio et al., 2016; Fahimnia et al., 2015; Liu et al., 2015), and its outcome is map-dependent, utilizing network theory to reveal the relevant structure of the data (Liu et al., 2015).

FINDING AND DISCUSSION

What are the research trends in scientific creativity within chemistry based on the year of publication?

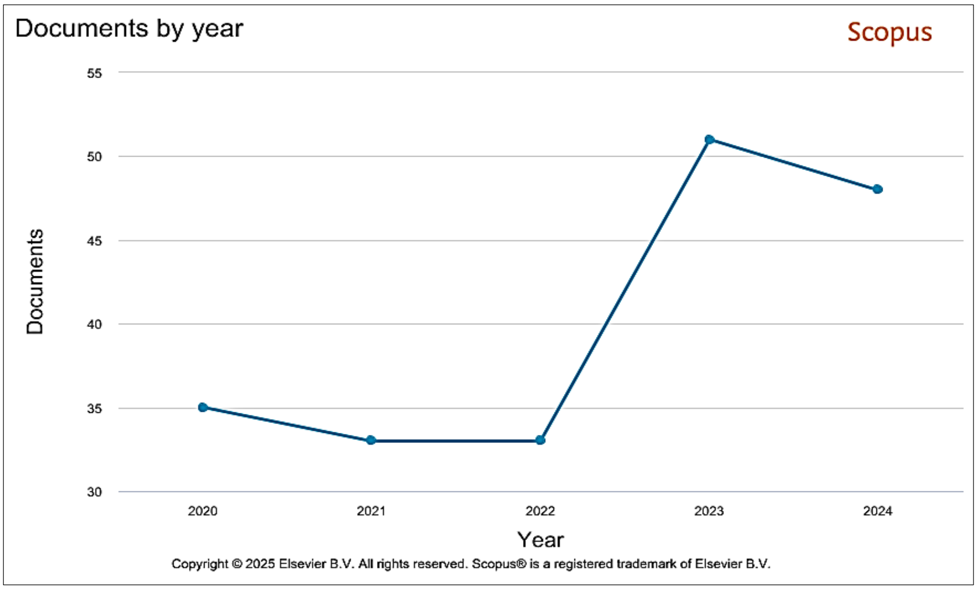

Figure 1: Plotting document publication by years

Figure 1 is a line graph illustrating the annual number of documents published in the journal from 2020 to 2024. The data encompasses publication counts that indicated notable fluctuations that reflect shifts in academic activity or research interest specifically related to the trends in scientific creativity in chemistry according to the publication year. The number of publications decreased from 35 in 2020 to 33 in 2021. An external factor (e.g., the slowdown caused by the global COVID-19 pandemic) may be a reasonable explanation for the small instability/decline in research productivity.

The number of publications peaks at 51 in 2023, indicating a large growth in publishing. The large rise indicates an explosion of recent research that may be driven by new discoveries in the field, funding opportunities, or renewed interest in some exciting new topics. The number of publications drops to 48 in 2024, down from the peak in 2023. The small decline may be an indication of a natural decline in interest and/or shifting interest to related or interdisciplinary areas.

Research production is not constant, as evidenced by the trends shown in Figure 1. Efforts may surround tightening procedures or workarounds on current field issues during the developmental phase, potentially showing stability from 2020-2021. The spike in 2023 represents a flurry of activity, often corresponding with discoveries, policy-driven funding, or a global focus on issues. The research area lifespan typically includes the expansion and exploration phase, followed by the integration or saturation phase- hence, the small dip in 2024 makes sense. Alternatively, this can represent a shift in publication strategy or moving funds to explore other emerging issues.

Figure 1 displays the ever-changing landscape of the amount of study on the subject of scientific creativity related to chemistry. Possible explanations for the plateau between 2020 and 2021 could be developmental efforts, such as removing bottlenecks or refining processes. It may also result from outside influences, such as the global COVID-19 pandemic. Starting in 2023, the publication rate spikes up to 51 articles. This could be due to new discoveries within the field, policy-driven funding, or a greater focus on current and future issues. With the typical lifetime of research being from exploration to stabilization, it is not a shock that the drop-off in 2024 came to fruition. Another explanation could be being absorbed by an emerging topic in chemistry or a change in how they go about publishing. Factors for research, such as technology advances, funding priorities, and global issues, could be interpreted from these oscillations. Understanding these dynamics is paramount for better resource allocation, finding new avenues of research, and promoting long-term growth in the field of scientific creativity in chemistry.

Who are the most productive authors of research?

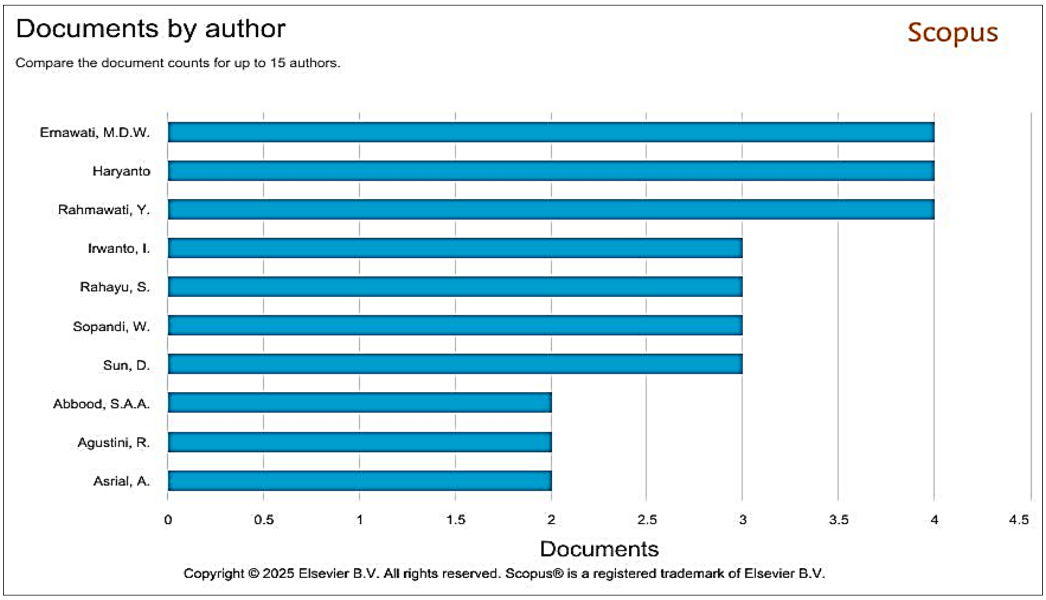

Figure 2: The most productive authors of research

To answer the research question, "Who are the most prolific authors of research?" Figure 2 displays the rate of production of writers who contribute to the research on the issue. Based on the chart, it is clear that the most productive authors are Ernawati, M.D.W., Haryanto, and Rahmawati, Y. The three writers have each contributed around four documents. Their regular production shows interest and skill in the subject and positions them as the dominant figures in setting the direction of the research. Other writers' documents, who have a moderate number of documents, such as Irwanto, I., Rahayu, S., and Sopandi, W., are around three but have lower productivity. The role of most productive writers in a collaborative research effort is to contribute actively, although quietly. Other top fifteen authors of Sun, D., Abbood, S.A.A., Agustini, R., and Asrial, A. have written documents between two to 2.5. To some extent, their position as top contributors demonstrates the highest commitment to improving the knowledge of the discipline, although productivity is not among the highest.

In the academic world, a small number of writers indeed control the production of research ventures that publish a lot of documents; this group probably has the most access to funding, partners, and know-how. Other less active writers also play important roles as collaborators or as young researchers who have a major influence on the future of the field. It is very important to acknowledge the most active writers to encourage cooperation and maximize their knowledge to advance research. However, to sustain the effort and diversify the area, it is also important to encourage researchers who are reasonably productive and in the development stage. Conclusively, findings reveal strategic involvement and funding decisions that can ensure academic advancement by highlighting the collaborative and dynamic nature of research production.

What type of documents are used for the subject of research?

Figure 3 provides an indication of the type of academic outputs that feed into the field of scientific creativity and chemistry, showing the distribution of document formats used in this area of study. Articles, reviews, conference papers, book chapters, and books are identified as the five main forms of publications. Ninety percent of publications in the dataset are articles, highlighting their importance in establishing credibility and expanding

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue III March 2025

knowledge through an extremely strict peer-reviewed process. Reviews represent only 5% of the total, yet are extremely useful for summarizing current knowledge and identifying trends, gaps, and possible directions for future research. Conference papers (2.5%) emphasize the importance of scientific conferences as places for exposing preliminary results and encouraging collaborative exchanges. However, books and book chapters (1% and 1.5%, respectively) are still valued for thorough theoretical discussion and multi-disciplinary explorations.

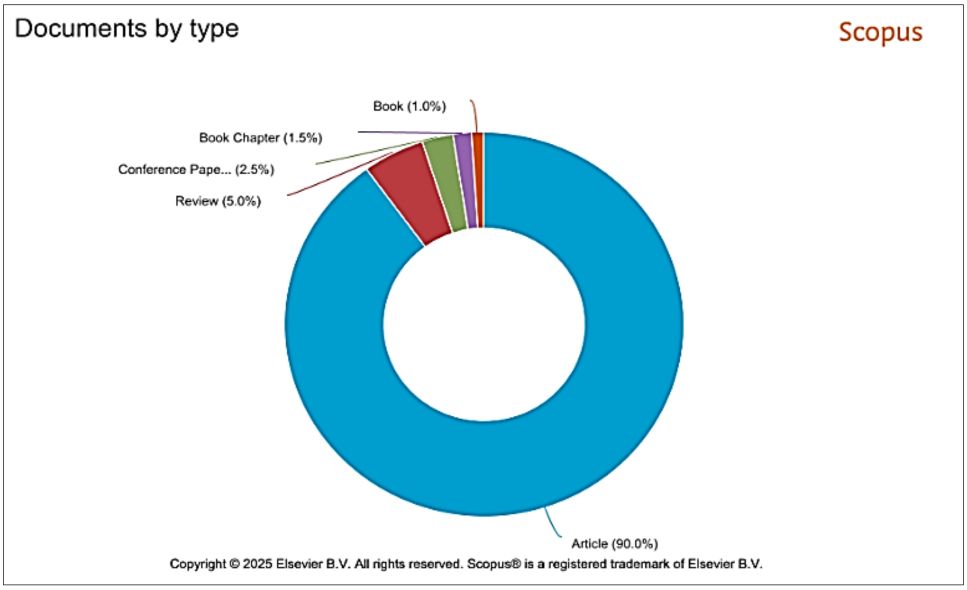

Figure 3: Type of documents used for the subject of research

The predominance of journal articles is consistent with the norms of the scientific community in which peer-reviewed publications are the ultimate sources of confirmation and sharing of research results. Reviews can provide scholars with an overview of the research landscape and the opportunity to build upon past work. Although fewer in number, conference papers still provide an important way to increase community involvement and advance ideas at an early stage. Although not the primary source of information in the field, books and book sections provide a valuable source for particular aspects of the field by allowing for more in-depth study and theory synthesis. These results indicate the crucial role of journal articles in sharing research and the supporting role of other types of documents. The field can be further enhanced by encouraging collaboration through active involvement in conferences and the publication of reviews. Besides the article-dominated scientific environment of scientific creativity and chemistry, books and book sections may be used as areas for more in-depth theoretical exchange.

What is network mapping based on the popular keywords relevant to the study?

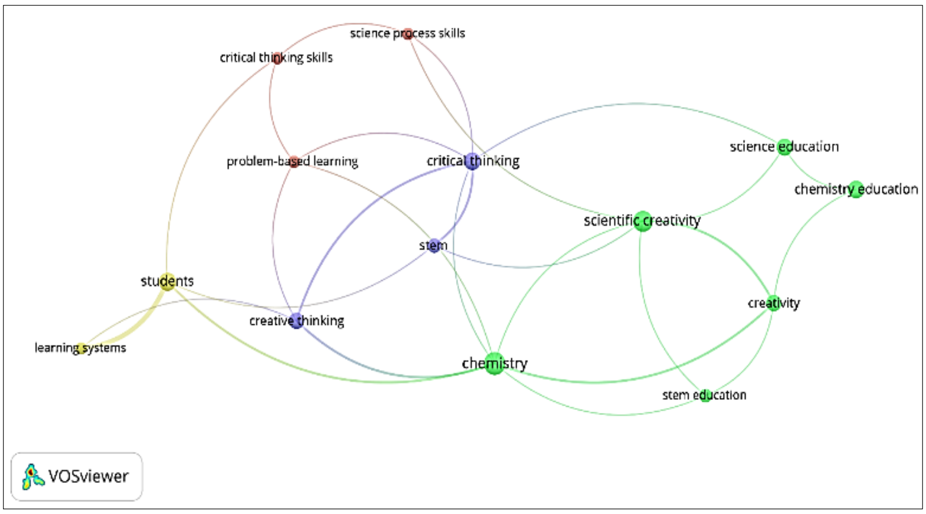

Figure 4: The popular keywords related to the study

The keywords visualization about chemistry and scientific creativity studies illustrated in Figure 4 draw attention to numerous interrelated themes and their prevalence in the area. Scientific creativity is at the core of this research. It is the most important word with a deep relationship with chemistry, STEM education, and creativity. With 17 appearances and an average citation count of 8.12, the phrase certainly is a key phrase in research and teaching. Similarly, the 22 appearances in chemistry can reflect both the theoretical and applications of science, which is strongly related to research and education. The importance of teaching creativity in chemistry subjects is reflected in these basic keywords.

Education is an important focus of the research, with keywords such as “chemistry education,” “science education,” and “STEAM education,” which reflect the effect of organized teaching and learning processes in stimulating original thought. For example, the significance of STEM education in innovation-based teaching and learning is reflected by the strong correlations between STEM education and scientific originality and creativity. Similarly, teaching and learning that enhances students’ problem-solving abilities and inventiveness pays close attention to cognitive competencies like creative and critical thinking. The global priority of education is to ensure the development of students’ innovative and critical thinking skills, preparing them to tackle essential issues in real-life situations.

The words “problem-based learning” and “science process skills” suggest that teaching methods are also important. These words reflect the field’s pedagogical philosophy, which promotes hands-on experience and the development of students’ critical and creative thinking. Importantly, these keywords are related to key themes like scientific creativity and critical thinking, which emphasize the importance of active learning. These methods enable students to engage deeply with scientific problems and provide innovative solutions. By focusing on practical and hands-on methods, scientific creativity research can cross disciplines and meet teaching and practical needs. Scientific creativity, STEM education, and critical thinking skills, which are related terms, reflect how the profession relies on multi-disciplinary and skills-based approaches to promote innovation. The results show the need for methodological innovations to enhance learning outcomes and embed creativity into teaching methods. The analysis will assist researchers and educators who wish to enhance scientific creativity in chemistry by guiding their future efforts to generate effective methods and practices.

What is network mapping according to co-authorship countries’ collaboration?

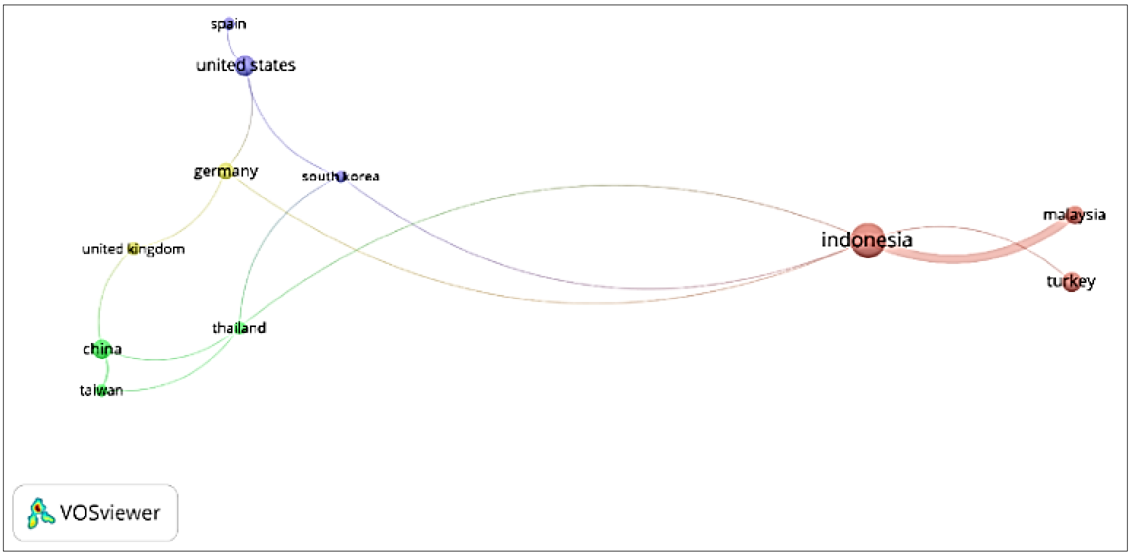

Figure 5: The co-authorship countries’ collaboration

The co-authorship analysis highlighted in Figure 5 revealed the patterns of international collaboration in the field of scientific creativity and chemistry, showcasing the diversity and strength of partnerships among nations. By tracing the co-authorship, the connection between countries in chemistry and scientific innovation can be seen, which presents the diversity of international relationships. As an important node of the collaboration network, Indonesia, as a center, presented 12 papers and was linked to South Korea, Turkey, and Malaysia. The rise as a center implied its role as a leader and participant, especially in Southeast Asia. The regional partnerships with

Malaysia and Thailand show the directions and problems to be solved, especially in scientific creativity and education.

The developed countries, for instance, the UK, the US, and Germany also have important roles. The connection between Germany, the US, and Indonesia shows its crucial role in different settings. The US also contributed greatly to international collaboration due to its powerful research infrastructure and strong knowledge. Meanwhile, with regional and cross-regional connections, rising countries such as Turkey and China have been more active in collaboration. The collaboration between China, Thailand, and the US also shows the sign of globalization in scientific creativity and chemistry.

This fact supports the importance of working together in global and regional collaboration to promote development in the scientific field. Localized research can focus on specific problems in chemistry education and scientific innovation. Indonesia's central role and collaboration with its neighbors can show these possibilities. The developed countries and the rising countries can bring distinct perspectives and methods, which can add to the knowledge of chemistry-based scientific creativity. The scientific creativity and chemistry are dynamic and cross-disciplinary. To promote it, regional networks need to be strengthened, the capacity of the rising countries needs to be built, and global collaborations need to be more inclusive.

What is network mapping based on citation by country?

Figure 6 shows the network mapping of the citation-based collaboration on scientific innovation and chemistry on a global scale. With the large links with the adjacent nations like Turkey and Malaysia, Indonesia plays a part in the web. Indonesia has risen to the forefront of Southeast Asian scholarship with 69 citations and eight publications, proving its dominance and leadership. These collaborations align with what the region values most, particularly in improving chemistry education and developing fresh ideas about scientific creativity. Malaysia has shown its importance as a regional partner through 50 citations and five papers, which proves its role in promoting localized knowledge sharing and addressing common problems.

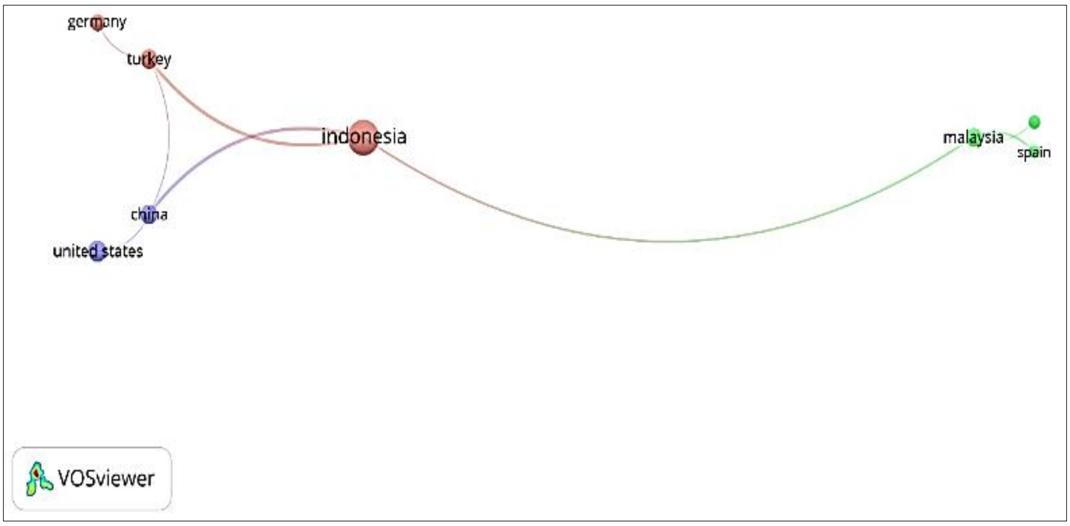

Figure 6: Network mapping

Some of the most influential industrialized nations, like the US, China, and Germany, are present in the network. China has the largest portion of the network, with 107 citations and large relationships with Indonesia and Turkey. This gives China its global role as the world leader in research volume and impact. Similarly, the US and Germany have had a heavy impact due to their massive research networks, which they use to expand the worldwide knowledge base. Small yet active nodes like the UK and Spain fill the network with their contributions to specialist domain advancements and collaborative clusters. These elements highlight the vast network of scientific creativity and chemistry research that is beyond economic and geographical barriers.

The analysis shows the importance of promoting collaborations both on a global and regional scale for more impact and exposure of research. Developed nations like Germany and China can light up innovation through cross-regional collaborations. At the same time, Indonesia and Malaysia will be in the best position to keep their leadership in regional relationships. Smaller donors like the UK and Spain must not be left behind to keep the research ecosystem diverse and inclusive. The results identify how important it is to fortify these networks to keep the world's scientific creativity and chemistry alive.

CONCLUSION

The bibliometric analysis that has been given is an effort to look at the dynamics of the scientific creativity of chemistry research in several aspects in general, namely publication patterns, patterns of authorship, types of documents, and collaboration networks. Yearly Trends of Research outputs indicate an increasing trend in publishing tendencies from 2020-2023, peaking in 2023. This increase matches the rising of funding and enthusiasm for creativity and chemistry, which is triggered by pressing social and educational problems worldwide. The slight drop in research done in 2024 may have indicated a natural stabilization or shift in the research's focal point. Sustainability and new research priorities are raised by such patterns, which may be due as much to the development of a field towards its explicit position in society as they are to the general growth of information generation.

Productive and Cited Authors Ernawati, M.D.W., Haryanto, and Rahmawati, Y. are the authors who are the most productive and routinely top in research outputs. The aforementioned results illustrate the important role that a small number of researchers have in shaping the future of chemistry and the concentration of knowledge within this group. Types of Documents Journal articles are the most common document form (90%), highlighting their importance in sharing high-quality, peer-reviewed research. In addition, conference papers (2.5%) and reviews (5% of the total) play a valuable role by providing venues for publishing preliminary results and synthesizing existing work. Books and book chapters are under-represented, which may reflect less of a focus on theoretical discourse and in-depth analysis, and there is room for diversity in the research outputs.

The network mapping of important keywords shows the themes and links within the research. There is a clear push towards multidisciplinarity and the inclusion of creativity into the classroom, as highlighted by the prominence of scientific creativity, STEM education, critical thinking, and chemistry education. These links show the research's devotion to solving complex problems using creative teaching and collaborative research. Indonesia plays a vital role in regional collaboration with countries such as Turkey and Malaysia, as highlighted in the analysis of co-authorship. Developed countries like the US and Germany are crucial in creating international collaborations while developing countries like China contribute to broadening the scope. These collaborations show the importance of inclusive and fair partnerships in improving the global research landscape. Visualization of the citation-based mapping shows the top three countries in the network, Indonesia, China, and Germany, and their respective contributions to the advancement of scientific creativity in chemistry. Indonesia's leading role in Southeast Asia, China's global influence, and Germany's developed research capacity illustrate the networked nature of research. Smaller contributors like the UK and Spain also enhance the network with their specialized work.

The dynamics of the state of scientific creativity and chemistry research shape the picture generated by bibliometric research. Documented papers dominate, the number of productive authors is growing, and the field as a whole is indisputably growing. The importance of inclusive research initiatives is highlighted via regional and global partnerships, while keyword and network mappings reveal the interdisciplinary and collaborative mindset behind the fields. Researchers, policy-makers, and educators can use these insights to prioritize future research directions better, build collaborative networks, and fill in any gaps that may exist. Stakeholders may promote varied contributions and sustained progress and increase the impact of scientific creativity and chemical research to address current issues by drawing on emerging patterns and networks. This study ensures a dynamic and productive research ecosystem, which sets the stage for evidence-based decision-making and further research.

ACKNOWLEDGEMENT

The authors extend their deepest gratitude to the School of Educational Studies, Universiti Sains Malaysia, Penang, Malaysia, for providing the necessary resources to carry out this research. They would like to acknowledge sincere appreciation to all peers and colleagues for their support and feedback.

REFERENCES

1. Al-Khoury, A., Hussein, S. A., Abdulwhab, M., Aljuboori, Z. M., Haddad, H., Ali, M. A., Abed, I. A., & Flayyih, H. H. (2022). Intellectual capital history and trends: A bibliometric analysis using Scopus database. Sustainability, 14(18), 1–22.
2. Allahverdiyev, M., & Yucesoy, Y. (2017). Development stages and types of glass art from past to present. Ponte, 73(4), 224–238. https://doi.org/10.21506/j.ponte.2017.4.53
3. Alves, J. L., Borges, I. B., & De Nadae, J. (2021). Sustainability in complex projects of civil construction: Bibliometric and bibliographic review. Gestao e Producao, 28(4), 1–21.
4. Appio, F. P., Cesaroni, F., & Di Minin, A. (2014). Visualizing the structure and bridges of the intellectual property management and strategy literature: a document co-citation analysis. Scientometrics, 101(1), 623–661. https://doi.org/10.1007/s11192-014-1329-0
5. Appio, F. P., Martini, A., Massa, S., & Testa, S. (2016). Unveiling the intellectual origins of Social Media-based innovation: insights from a bibliometric approach. Scientometrics, 108(1), 355–388. https://doi.org/10.1007/s11192-016-1955-9
6. Di Stefano, G., Peteraf, M., & Verona, G. (2010). Dynamic capabilities deconstructed : a bibliographic investigation into the origins, development, and future directions of the research domain. Industrial and Corporate Change, 19(4), 1187–1204. https://doi.org/10.1093/icc/dtq027
7. Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. International Journal of Production Economics, 162, 101–114.
8. Gu, D., Li, T., Wang, X., Yang, X., & Yu, Z. (2019). Visualizing the intellectual structure and evolution of electronic health and telemedicine research. International Journal of Medical Informatics, 130, 1–11.
9. Kocoglu, A., & Kanadlı, S. (2024). Effect of argumentation-based instruction on student achievement: a mixed-research synthesis. Asia Pacific Education Review, 25, 1051–1081. https://doi.org/10.1007/s12564-024-09945-6
10. Lai, C. K., Haim, E., Aschauer, W., Haim, K., & Beaty, R. E. (2024). Fostering creativity in science education reshapes semantic memory. Thinking Skills and Creativity, 53, 1–11. https://doi.org/10.1016/j.tsc.2024.101593
11. Li, H., An, H., Wang, Y., Huang, J., & Gao, X. (2016). Evolutionary features of academic articles co-keyword network and keywords co-occurrence network: Based on two-mode affiliation network. Physica A: Statistical Mechanics and Its Applications, 450, 657–669. https://doi.org/10.1016/j.physa.2016.01.017
12. Liu, Z., Yin, Y., Liu, W., & Dunford, M. (2015). Visualizing the intellectual structure and evolution of innovation systems research: a bibliometric analysis. Scientometrics, 103(1), 135–158. https://doi.org/10.1007/s11192-014-1517-y
13. Nurdullayevna, Zz. G., & Kuanishkyzy, A. D. (2024). Formation of student's creative interest in chemistry. ILIM, 39(1), 47–63. https://doi.org/10.47751/skpu.1937.v39i1.4
14. Nursiwan, W. A., & Hanri, C. (2023). Relationship between level of scientific creativity and scientific attitudes among prospective chemistry teachers. International Journal of Evaluation and Research in Education, 12(1), 174–179. https://doi.org/10.11591/ijere.v12i1.22852
15. Nursiwan, W. A., Hanri, C., & Ibrahim, N. H. (2023). Implementation of Scientific Creativity Among Chemistry Teachers. Asian Journal of Research in Education and Social Sciences, 5(4), 361–367. https://doi.org/10.55057/ajress.2023.5.4.36
16. Pertiwi, N. P., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing critical thinking skills through stem problem-based contextual learning: an integrated e-module education website with virtual experiments. Journal of Baltic Science Education, 23(4), 739–766. https://doi.org/10.33225/jbse/24.23.739
17. Ramly, S. N. F., Ahmad, N. J., & Yakob, N. (2022). Development, validity, and reliability of chemistry

scientific creativity test for pre-university students. International Journal of Science Education, 44(14), 1–16. https://doi.org/10.1080/09500693.2022.2116298

18. Singh, J., & Kaushik, D. (2020). The study of the effectiveness of the inquiry based learning method in chemistry teaching learning process. Adalya Journal, 9(4). https://doi.org/10.37896/aj9.4/058
19. Stepanov, S. Y., & Orzhekovskiy, P. A. (2022). Individualization and Digitalization of Creative Development of Students in Chemistry Lessons. Acta Biomedica Scientifica, 7(2), 212–222. https://doi.org/10.29413/ABS.2022-7.2.22
20. Tseng, Y. J., Hong, Z. R., & Lin, H. S. (2024). Exploring high school students' chemical explanatory levels of thin-layer chromatography through reflective inquiry. Journal of Chemical Education, 101(9), 3635–3642. https://doi.org/10.1021/acs.jchemed.4c00084
21. Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3
22. Van Eck, N. J., & Waltman, L. (2017). Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics, 111(2), 1053–1070. https://doi.org/10.1007/s11192-017-2300-7
23. Van Eck, N. J., & Waltman, L. (2007). Bibliometric mapping of the computational intelligence field. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 15(5), 625–645.
24. Verbeek, A., Debackere, K., Luwel, M., & Zimmermann, E. (2002). Measuring progress and evolution in science and technology - I: The multiple uses of bibliometric indicators. International Journal of Management Reviews, 4(2), 179–211.
25. Wu, Y. C. J., & Wu, T. (2017). A decade of entrepreneurship education in the Asia Pacific for future directions in theory and practice. Management Decision, 55(7), 1333–1350. https://doi.org/10.1108/MD-05-2017-0518
26. Xu, S., Reiss, M. J., & Lodge, W. (2024). Enhancing scientific creativity through an inquiry-based teaching approach in secondary science classrooms. International Journal of Science Education, 1–18. https://doi.org/10.1080/09500693.2024.2419987
27. Zhao, X. (2017). A scientometric review of global BIM research: Analysis and visualization. Automation in Construction, 80, 37–47. https://doi.org/10.1016/j.autcon.2017.04.002